



West Maui Wahikuli & Honokōwai Priority Watershed Area
REEF CONDITION REPORT

December 2016



Background

- The State of Hawaii and partners established the West Maui Priority Watershed Area in year 2010 with the intent of making this a focal location for coral reef research and management initiatives. The USCRTF added a priority watershed partnership designation to Wahikuli and Honokōwai in 2011, and the [West Maui Ridge to Reef Initiative](#) (WMR2R) was formalized in 2012 creating layers of commitment to interagency and community partner collaboration in this area of West Maui. Ongoing and planned projects enacted to improve condition of reefs include the establishment of the Kahekili Herbivore Fisheries Management Area (KHFMA) in July 2009, and the initiation of several WMR2R projects intended to reduce extent and impact of land-based sources of pollution. Summarized below is what is known about current status and recent trends of local reefs in order to provide a baseline against which future condition can be assessed.

Coral Reef Habitats & Survey Data for Wahikuli and Honokōwai

- **There is considerable variability in both condition and characteristics of coral reef and hardbottom habitats within the Wahikuli and Honokōwai watersheds.** Several portions of the hardbottom habitat in this area consists of patchy or low coral cover habitat, but there are also sections of coastline with coral-rich and structurally complex reefs - in particular in the ‘Canoe Beach’ area and within the Kahekili Herbivore Fisheries Management Area (KHFMA).
- **There is a growing body of survey data from the watershed.** Available data is now sufficient to draw general conclusions about overall status of the main reef areas within the watershed. However, other than inside the Kahekili HFMA, and at the long-term fixed CRAMP benthic sites, there are not yet sufficient time series to draw conclusions about temporal trends. One goal of this report is to provide the basis for such assessments in the future.
- **Priority watershed areas have been divided into 4 ‘sections’ to reflect the variability of habitat types and data-availability:** ‘Canoe Beach’, ‘Black Rock’, ‘Kahekili HFMA’, and ‘Mahinahina/North Honokōwai’ (figure 1), and here we report on the status of coral reefs and associated fish assemblages at that scale. Where possible we report not only current conditions, but also longer-term trends, and attempt to place those values in context by comparing against similar data from elsewhere in Maui and beyond.

Coral Reef Status and Trends

Kahekili Herbivore Fisheries Management Area (KHFMA)

- The KHFMA section contains substantial areas of well developed reef, and across all hardbottom areas in that section, coral cover averaged 34.2% over last 5 years, considerably higher than the average for all hardbottom habitats in Maui of 18.9%. Over the same time period, mean biomass of fishes generally, including of ‘key herbivores’ (parrotfishes and surgeonfishes), was around twice the average from Maui hardbottom sites (comparison points for both derived from NOAA CREP surveys around Maui in 2010-15).
- The DAR-CREP monitoring of the KHFMA provides clear evidence of positive change since the KHFMA was established, including increased biomass of parrotfish and surgeonfishes and increased cover of crustose coralline algae (CCA, that is considered to be beneficial for coral growth and recruitment). Following earlier declines in coral cover (between 2008 and 2010) coral cover stabilized within the KHFMA and then slightly ticked up in late 2013 and into 2015. Data from the CRAMP site at Kahekili Beach Park indicates that, for that one area of shallow reef, coral cover has been relatively stable over around the last decade, having previously declined between about 1998 and 2000.
- Compared to other areas covered by this report, reefs in Kahekili had notably higher biomass of parrotfishes and cover of CCA, which is consistent with other evidence described above showing recovery within the KHFMA since herbivore protection was implemented in 2009.

Black Rock

- There is very little reef habitat in the ‘Black Rock’ section, and therefore it is not problematic that there is also very little survey data from there.

Canoe Beach

- The Canoe Beach section contains an extensive stretch of well-developed reef, although that high coral cover habitat does not appear to extend much beyond around 30 ft deep. Mean coral cover derived from 2015 ‘KHFMA’ surveys in that coral rich habitat was 47.7%. Similarly, coral cover was estimated to be 47% at the ‘Coral Health’ sites when those were surveyed in 2014. As macroalgal cover was also low, these reefs appear to be in relatively good condition compared to many other reefs around Maui.
- Fish survey data from the intensive belt transect surveys conducted in 2015 indicated that fish biomass, including herbivores, was above average for Maui reefs. One caveat is that the Canoe Beach survey data is only available from the coral rich habitat, whereas the comparison data come from a much wider range of habitats. Nevertheless, it appears that Canoe Beach fish populations were in relatively good condition at the time of the 2015 surveys – particularly in the more northerly parts of that reef. The only fish trend data available from the region comes from the ‘DAR resource fish’ surveys at a single 12m deep site near the southern edge of the main reef tract. Data from those surveys indicates that biomass of targeted fishes, including parrotfishes and surgeonfishes, has been relatively low at that site, but there is no clear indication of an up or down trend there.

Mahinahina / North Honokowai

- The ‘Mahinahina/North Honokōwai’ contains patchy reef habitat of highly variable condition, but including some areas of well developed reef and high coral cover. Mean coral cover in surveyed reef habitats was estimated at 33.4%. However, we do not have cover data from the large areas of low relief patchy pavement and sand, where coral cover is mostly very low. At the Mahinahina CRAMP site there appears to have been a small decline in mean coral cover since the site was established in 2004 (from 31.0% in 2004, to 26.8% in 2015). Coral cover at two ‘Coral Health’ sites established in 2014 adjacent to the Mahinahina and Honokōwai stream drainages was highly, ranging between 5–43% and 38-40%, respectively.
- Biomass of target fishes at the ‘DAR resource fish’ site was low compared to other sites in Maui surveyed by that program. However, more widespread fish surveys using intensive small-scale belt transects (i.e. the method applied in the KHFMA) indicated relatively healthy coral reef fish populations in the surveyed habitats, particularly of surgeonfishes.

Coral Reef Condition Status and Trends Schematic. Hatched lines indicate that there is insufficient data to draw conclusions about status or trends. Green indicates ‘good’ condition (i.e. high biomass, high coral or CCA cover, low macroalgal cover; orange means condition is around average for Maui reefs. No condition indices were deemed poor compared to typical reefs in Maui. Arrows are intended to give an indication of recent trends. NOTE that judgments are largely subjective. There will be scope for a more formal assessment as more data is gathered over longer timeframes. We advise readers to examine the more detailed data provided below.

SECTION	Fish Biomass	Key Herbivore	Coral Cover *	Crustose Coralline Algae [CCA]	Macroalgal Cover
Canoe Beach					
Kahakili HFMA	→	↑	→	↑	↓
Mahinahina/ North Honokōwai			↓		

Note (*) Coral cover has declined at Mahinahina CRAMP site since it was established in 2004, but recent trends appear flat. Coral has also shown longer term decline at the Kahekili CRAMP site, but for that section of coastline we have wider trend information suggesting there may have been some recovery between 2012 and 2015

Survey Outlook

- Broadening of the intensive belt transect survey program in 2015 from just KHFMA into surrounding areas has filled many of the data gaps at Canoe beach and North Honokōwai. However, surveys in those areas have largely been conducted in coral rich areas, and therefore those areas do not have the same depth of information as is available for the KHFMA. Maintenance of that survey program will allow for meaningful estimation of change in time.
- Collaborative monitoring of the KHFMA has demonstrated substantial changes in reef assemblages since closure, but given the lifespans of the fishes protected (2 or more decades for many species) and the expected lag in response of slow growing corals, it will likely take several more years before the full effects of closure are known.
- The recently established 'Coral Health' sites were designed to generate high quality data on benthic cover and coral demographics at the 3 sites where survey transects are clustered – one in Canoe Beach, one close to Honokōwai Point, and one just north of the deeper Mahinahina CRAMP station. Periodic resurveying of those sites will provide early indication of change in coral assemblages and health in reef areas adjacent to terrestrial drainage points.
- As with nearly any such area in Hawaii and beyond, there have been a variety of survey programs with different methods and designs. While there are frequently good reasons for developing specific programs for particular locations and questions, the diversity of survey approaches complicates larger scale and comparative assessments. To a large degree, the main monitoring programs operating in Hawaii have coalesced on a core group of survey approaches, which will greatly facilitate future data sharing and pooling. More work to develop and improve calibration coefficients will be necessary to maximize the scope for such pooling.
- The information presented here does not include any data gathered after the 2015 coral bleaching event. It is a near certainty that some measureable coral mortality occurred during and after that event, and thus we can expect some decline in coral cover to be evident in the next iteration of this report.

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Background and Characterization of Nearshore Reef Habitats

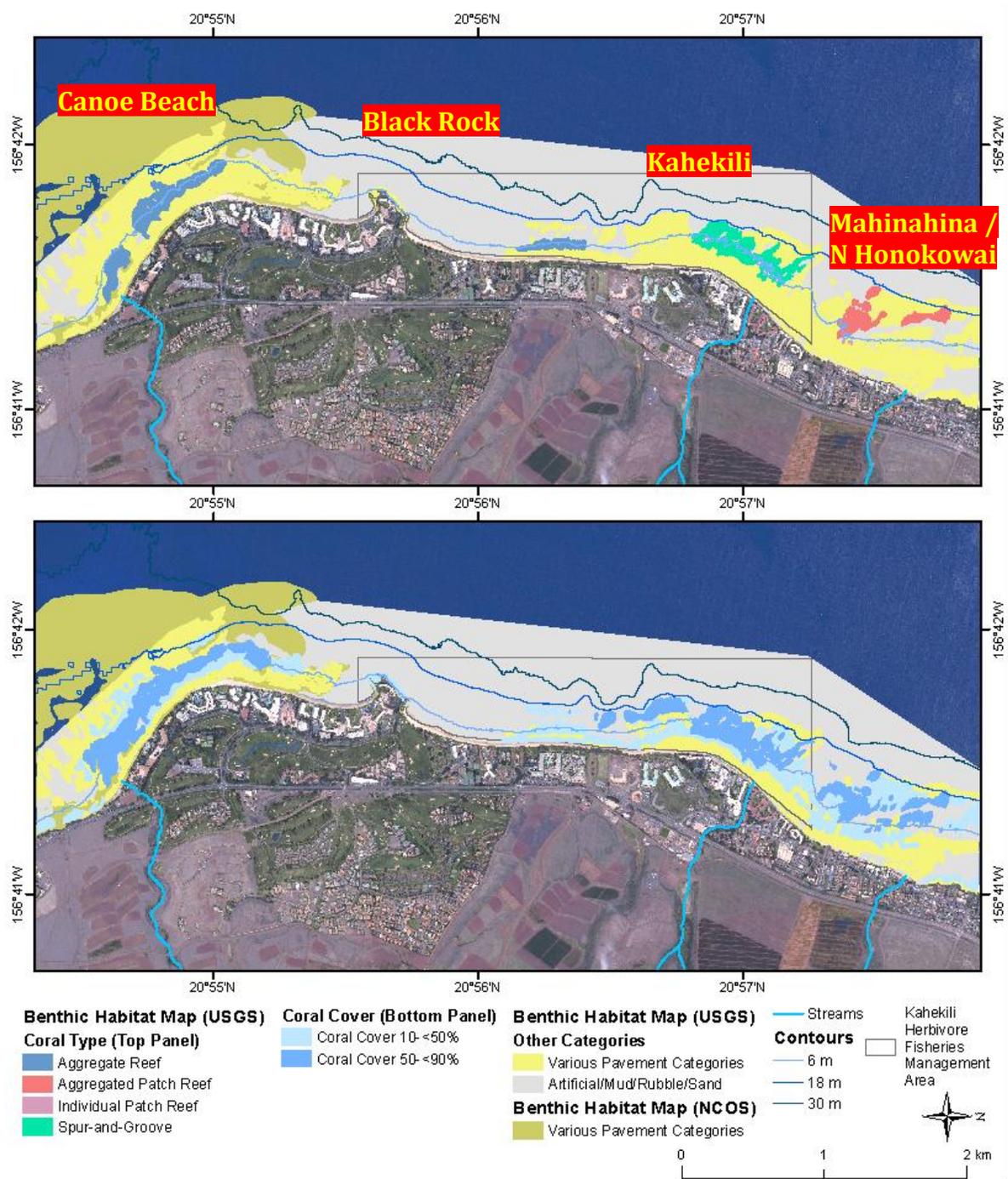


Figure 1. Maps of (a) reef type; and (b) coral cover categories at West Maui priority watershed. Data from USGS report.

The West Maui priority site contains 4.4 miles of coastline, which we have divided into 4 sections, based on reef structure and availability of data (fig 1): Hanaka'ō'ō Beach, commonly known as 'Canoe Beach' at the southern edge of the priority site has a large well developed nearshore reef and substantial hardbottom pavement areas with scattered coral extending into deeper water; the Pu'u Keka'a or 'Black Rock' section is largely sand-habitat with some coral habitat on Black Rock itself; 'Kahekili HFMA' contains extensive and varied reef habitats including

shallow fringing reef, offshore forereef, as well as complex spur and groove habitat around Honokōwai point; reef habitats in the furthest north section ('Mahinahina/North Honokōwai') consist largely of reef pavement and sandy zones, but with patches of richer coral habitat. Because of the size of the priority site and the diversity of habitat types, reef conditions are primarily reported at the level of these sub-sections.

Data Sources and Summary Metrics

Figure 2 shows the locations of sampling sites for all fish or benthic assemblage fish or benthic data gathered by DAR or CREP survey programs. We did not attempt to collate data from the several research efforts inside the Kahekili HFMA (KHFMA) in recent years, but those data could potentially be included in future or supplementary reports.

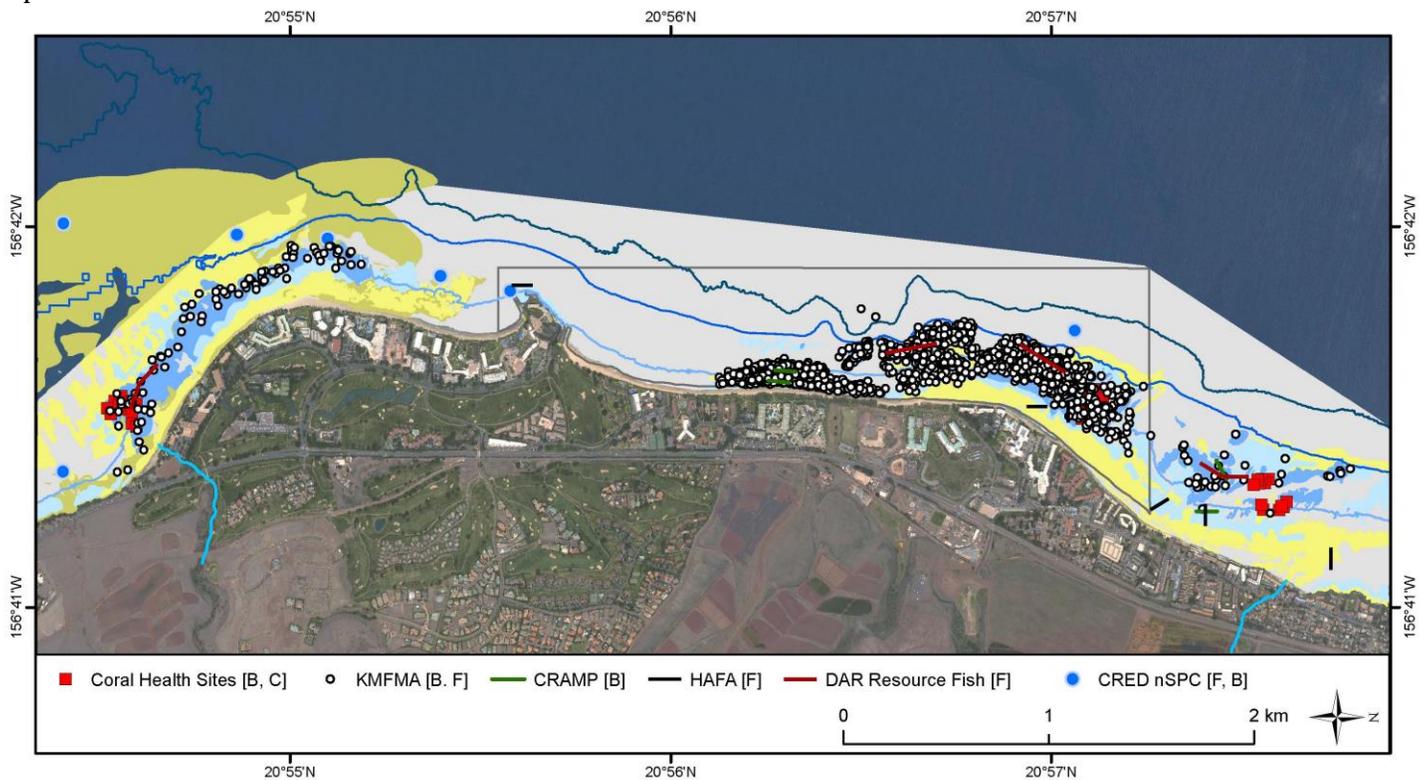


Figure 2. Coral reef surveys inside the priority watershed.

There are 4 main survey programs that we draw data from (see below). The locations of survey sites of each type are showing in figures 2-6.

- 'CRAMP' (Hawaii Coral Reef Assessment and Monitoring Program; <http://cramp.wcc.hawaii.edu>) sites involve photo-surveys of benthic cover in fixed permanent transects. Each survey location has two 'sites', generally at ~3m and ~7m; with each site consisting of 10 replicate transects. Within the watershed, there are 2 CRAMP locations: 'Kahekili' and 'Mahinahina' (figures 2, 5 & 6). The Kahekili CRAMP location was established in 1999 and Mahinahina in 2004.
- DAR 'Resource Fish' surveys are timed swims, in which divers focus on fishery target taxa and size ranges (for consistency only data on fishes > 15 cm are used for this report). 'Resource' fish surveys are conducted 1-3 times a year at each site, with each survey covering ~250m long stretch of reef starting from a fixed location. Within the watershed, there are 'resource' fish sites at Canoe Beach, Kahekili (2 sites), and Mahinahina (figures 2, 3, 5 & 6), all at ~10m deep. We use 'resource fish' surveys from 2008 onwards. However, no resource fish surveys have been conducted at the sites in this area since 2014 – as DAR has

shifted effort to other types of intensive surveys around Maui. However, much of the information that was previously generated by these surveys is being better gathered by the 'KHFMA' surveys described next.

- KHFMA surveys were established to test the effectiveness of the Kahekili HFMA. They began in January 2008, and have involved 1 or 2 'rounds' of intensive surveys every year since. Surveys identified as 'KHFMA' in figure 2 and other survey maps consist of fish counts and benthic photo-surveys at multiple 25m transects randomly located within hardbottom habitats. The great majority of these have been conducted within the Kahekili HFMA (figures 2 & 5). However, beginning in 2015, additional such surveys were conducted in reef areas on either side of the Kahekili reserve, at Honokowai and Canoe Beach.
- 'Coral Health' sites are locations where there are co-located benthic cover, coral condition, and coral demographic surveys. Three clusters of those were established and sampled in June & July 2014 - at Canoe Beach, Honokōwai (inside Kahekili HFMA), and Mahinahina (figures 2, 3, 5 & 6). In addition, comparable data has been gathered on one occasion at the location of the Kahekili CRAMP stations (figures 2 & 5). It is important to recognize that these sites were deliberately located relatively close to stream and drainage outflows. They are therefore likely to be sensitive to changes in watershed management and other factors that cause variation in sediment input. However, by design, they are not representative of the wider reef tracts they are located within.

As shown in figure 2, there are also CREP or DAR data from two other programs: 'HAFA' surveys, and 'CREP SPC'. The HAFA surveys are timed swims conducted by snorkel in very shallow nearshore habitats (~2 m). Because of the very narrow focus of that program, and because there are relatively few data from the priority watershed we have not included that data beyond showing site locations in figure 2. 'CREP SPC' surveys are conducted by CREP during the MHI-wide randomized surveys conducted for the Pacific Reef Assessment and Monitoring Program (http://www.pifsc.noaa.gov/cred/pacific_ramp.php). That program has been designed to assess island-scale and larger reef assemblages, and hence the 4 sites that randomly fell within the watershed (figure 2) are far insufficient to allow for their use.

Summary of Available Survey Data

There are data from a variety of survey programs, established with a range of different goals. The KHFMA program is the only of these programs that attempts to be representative of reef habitats at a scale comparable to or within the scale of this report – in that case, surveys are widely distributed across pavement and reef areas within the KHFMA, and have sufficient replication to draw strong conclusions about fish and benthic condition status and trends over time in the KHFMA. The expansion of that survey program to Canoe Beach and Mahinahina in 2015 has greatly improved the basis for assessing status of those areas.

There is considerable value in other programs, for example, the CRAMP sites provide very high quality information about status and trends in benthic cover at the location of the survey transects; similarly the coral health sites established in 2014 will provide scope for assessing changes in coral condition and benthic assemblages along gradients in proximity to stream mouths/drainage points at Canoe Beach, Honokōwai, and Mahinahina, i.e. reef areas that would likely most immediately respond to changes in upslope land based pollution management projects underway through the West Maui Ridge to Reef Initiative.

Other survey data come from larger-scale programs conducted by DAR or CREP that focus on particular habitats or depth ranges, i.e. those surveys are not intended to be representative of specific local reef as a whole, but are instead part of larger-scale assessments of trend or broad condition. Where those data are used below, it should be understood as representing best available data; status and trend information from those sites does not necessarily represent the totality of reefs in the priority watershed.

Reef Condition Metrics

Standard reef condition metrics are used to quantify reef condition in ways that are consistent with reporting at other NOAA coral program priority sites. By definition standardized metrics simplify complex ecological relationships and processes in ways that lose considerable amounts of information. Nevertheless, they provide information on aspects of condition that scientists and managers have deemed to be particularly meaningful, and which are widely used as coarse indicators of condition. For several of those target metrics, we do not currently have sufficient information to assess conditions. This summary document is partly intended to highlight current data gaps.

Table 1a. Condition metrics - Fish

Fishes	Metric	Purpose / Justification
	Total Fish Biomass	Total fish biomass represents what is typically an estimate of standing stock (weight) of reef fishes per unit area. Biomass is affected both by the number and the size distribution of local fishes, and is widely used as an indicator both of fishing impacts and of overall fish assemblage status.
	Key Herbivore Biomass (parrotfish & surgeonfish)	Large populations of herbivorous fishes will tend to maintain local algal communities in cropped states (e.g. CCA) that are considered most suitable for coral growth, recruitment and persistence. The KHFMA was in part set up to assess the scope for increased herbivory to promote conditions that allow corals to thrive on local reefs.

Table 1b. Condition metrics

Benthos	Metric	Purpose / Justification
	Benthic % Cover from Photo Transects – i.e. Upper Canopy Cover	
	Hard Coral	Reefs with high coral cover are generally actively growing and structurally complex environments. Coral cover is an integrated measure of growth, recruitment, mortality, and partial mortality of corals. Thus, high or increasing coral cover is indicative of an environment suitable for a coral reef to thrive.
	Crustose Coralline Algae [CCA]	CCA appears as hard, typically pink, rock-like substrate. High cover of CCA is generally indicative of algal growth being well controlled by resident herbivores. Compared to other algae that can occupy reef substrate, CCA is relatively benign or positive to corals – including that coral larvae will preferentially settle on some forms of CCA.
	Macroalgae	Macroalgae are structurally complex, generally fleshy and upright algae. While healthy reefs can have considerable macroalgae, increases in macroalgae or transitions from coral to conspicuous macroalgal cover are likely indicative of declining environmental quality for coral.
	Coral Condition & Demographics	
	Coral Recruitment	Juvenile colonies can be distinguished in the field by a distinct tissue and skeletal boundary (not a fragment of larger colony). This parameter measures the influx of new members into the population by sexual reproduction. The establishment of new coral recruits indicated good conditions for reef development and growth
	Coral Condition	Coral bleaching and disease are health impairments that interfere and limit a coral's ability to perform normal physiological functions (maintenance, growth, and reproduction). They are typically caused by a number of agents, including, environmental factors such as nutrients, toxicants, and climate; pathogens including bacteria and viruses (infectious agents); and inherent or congenital defects. Coral bleaching and disease have become central topics of discussion among coral reef managers, scientists, and the general public, largely because of the alarming rate at which these threats have increased in the last two decades.

Canoe Beach Section

Available Survey Data

Although the Canoe Beach section contains large expanses of well-developed coral reef as well as extensive pavement habitats, there has been rather little available survey data from this section until the 'KHFMA' surveys were extended to this area In 2015 (Figures 1, 2 & 3). Fish and benthic data is available from each of those 'KHFMA' sites, which therefore provide a good overall view of recent condition in the main well-developed reef tract. In addition, there are benthic cover and coral condition data for the 'Coral health' sites surveyed in July 2014. The only current trend data comes from 1-3 surveys per year at the 'Resource fish' site since 2008.

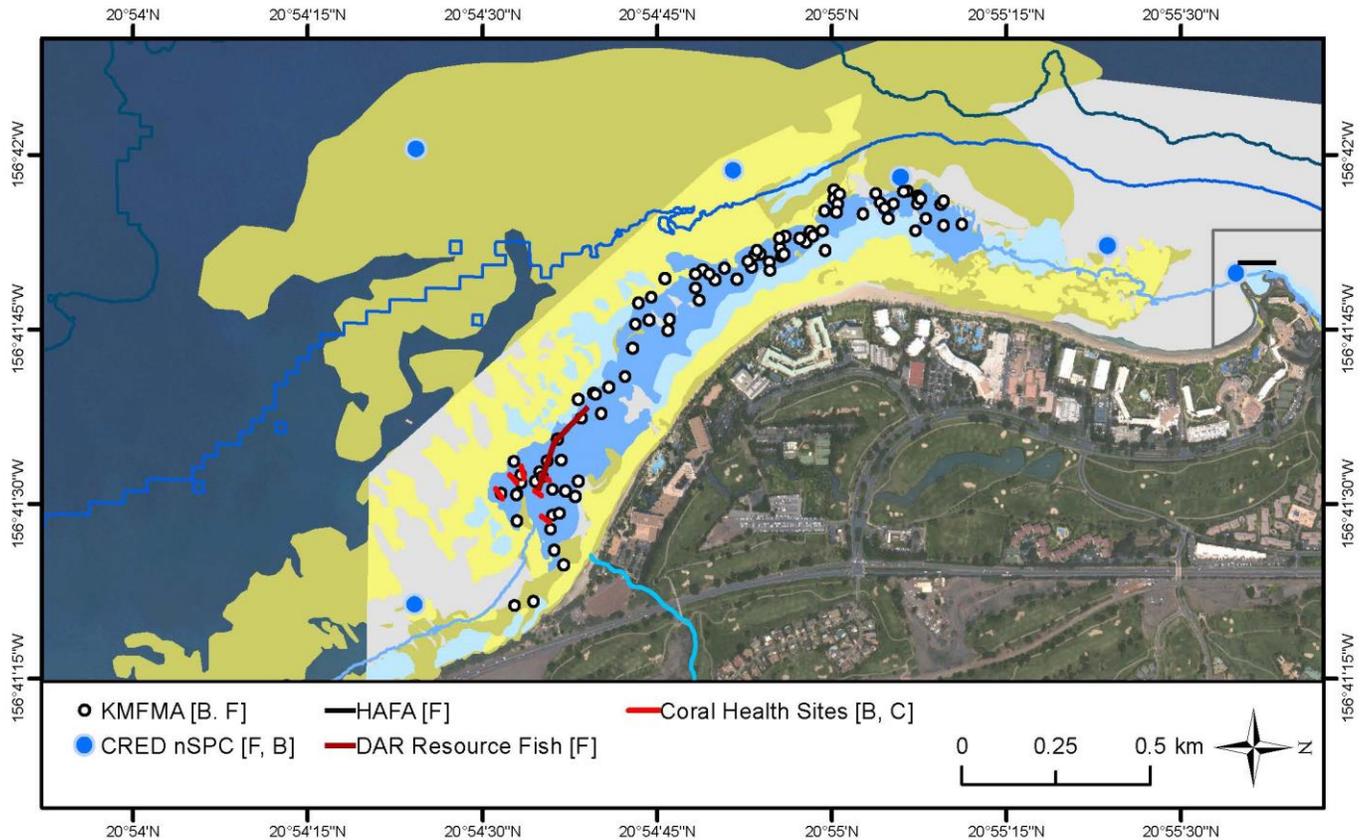


Figure 3. Available survey data from Canoe Beach Section

Benthic Condition Metrics – Canoe Beach

Table 2a. Mean ± SE benthic cover from coral health site surveys and from randomized belt transects. Coral Health Site data are derived from 3 transects at <20 ft deep. Canoe Beach high coral sites are the 44 haphazard surveys that fell on the USGS Coral 50-90% strata (i.e. dark blue zone in figure 3). CREP RAMP comparison come from the analysis of 2010-2015 RAMP benthic images from all sites at comparable depth (<60ft). Randomized belt transects use the approach initially implemented inside the KHFMA

	Random belt transects in Coral '50-90%' Habitat 2015	'Coral Health' site 2014	CREP RAMP (2010-2015)	
			Maui	All MHI
Hard Coral	47.7 ± 2.0	47.0 ± 3.6	18.9 ± 1.9	12.0 ± 0.5
Macroalgae	0.0 ± 0.0	0.2 ± 0.2	3.9 ± 0.6	3.6 ± 0.3

CCA	6.3 ± 0.2	1.3 ± 0.8	5.3 ± 0.5	4.1 ± 0.2
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Table 2b. Demographics (Density colonies/m²) Data are Mean ± SE. CREP comparisons are for sites <60ft of water from 2013 surveys.

	'Coral Health' site 2014	CREP RAMP (2013)	
		Maui	All MHI
Juvenile colonies	8.6 ± 3.4	5.1 ± 1.4	3.9 ± 0.4
Adult colonies	27.0 ± 4.9	11.2 ± 2.9	6.8 ± 1.2

Table 2c. Coral Health (%). Data are Mean ± SE. CREP comparisons are for sites <60ft of water from 2013. CRAMP and CREP data collected using slightly different methods, which means that estimates are not exactly comparable (different survey areas yield somewhat different estimates of disease prevalence). Surveys conducted in Oct 2014;

	Coral Health Site 2014	CREP RAMP (2013)	
		Maui	All MHI
Coral bleaching	5.5 ± 0.2	2.0 ± 0.5	2.0 ± 0.5
Disease -Growth anomalies -Recent tissue loss	0.4 ± 0.2 0.0	1.0 ± 0.7 0.5 ± 0.2	0.3 ± 0.1 0.1 ± 0.1

Fish Condition Metrics – Canoe Beach

Table 3. Mean ± SE fish biomass from Canoe Beach DAR Resource Fish site and from randomly located belt transect surveys. Note that Maui resource fish average comes from all other resource fish sites at comparable depth in Maui. Randomized belt transect surveys were conducted in 2015 in Coral 50-90% habitat (dark blue in figure 3), using methods first implemented in the KHfMA. The closest large-scale comparison for those data the averages of CREP surveys around Maui in 2010-2105.

BIOMASS (g /m ²)	Random belt transects 2015 Canoe Beach Coral 50-90%	CREP RAMP 2010-2015	DAR Resource Fish (2011- 2015)	
		Maui	Canoe Beach	Maui
All Fishes	47.8 ± 6.3	25.8 ± 2.3	6.7 ± 2.4	16.1 ± 1.3
Parrotfish	4.4 ± 0.1	2.8 ± 0.6	1.0 ± 0.3	2.6 ± 0.2
Surgeonfish	14.9 ± 1.8	10.0 ± 1.0	4.5 ± 1.8	7.7 ± 0.8

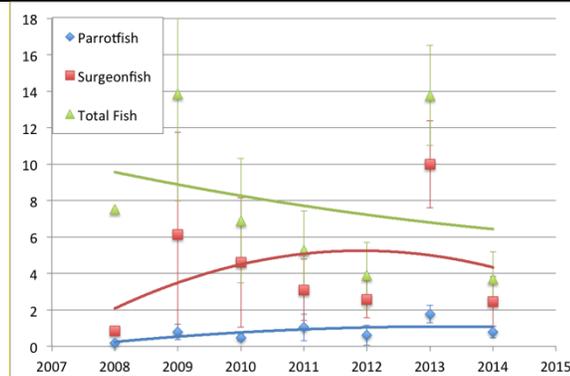


Figure 3A. Fish Assemblage Trends. Canoe Beach Resource Fish Surveys.

Summary

Data from belt transect surveys and from 'Coral Health' sites both indicate high coral cover and low macroalgal cover on the Canoe Beach reef (Table 2a). Those data all come from coral rich areas (i.e. they do not include data from pavement or rubble habitats shown in Figure 3). Nevertheless, it is clear that there is an extensive section of Canoe Beach reef that is in relatively good condition.

We have two sources of data to assess fish populations at Canoe Beach. Data from 'resource fish' surveys conducted towards the southern edge of the Canoe Beach reef tract (Figure 3), indicate that biomass of medium and large fishes of target families, and of parrotfishes and surgeonfishes, is below the average of other DAR Maui resource fish sites in the same depth range (Table 3). Unsurprisingly given the small sample size, data are quite variable from year to year, but there is no clear evidence of an overall upward or downward trend in fish condition at that site (Figure 3A).

However, the randomized belt transect surveys, which are much more broadly spread across the Canoe Beach reef tract, indicate substantially healthier fish stocks, which are likely above average for Maui reefs (Table 3). Biomass of parrotfishes and surgeonfishes at Canoe Beach are both lower than inside the Kahekili Herbivore Fisheries Management Area (Tables 3 & 5), in spite of the fact that Canoe Beach data is for only the coral rich habitat (dark blue area in figure 3), whereas Kahekili data cover a much broader range of habitat areas.

Black Rock Section

The Black Rock section contains very little coral habitat (figure 2). Available data are not sufficient for meaningful assessment.

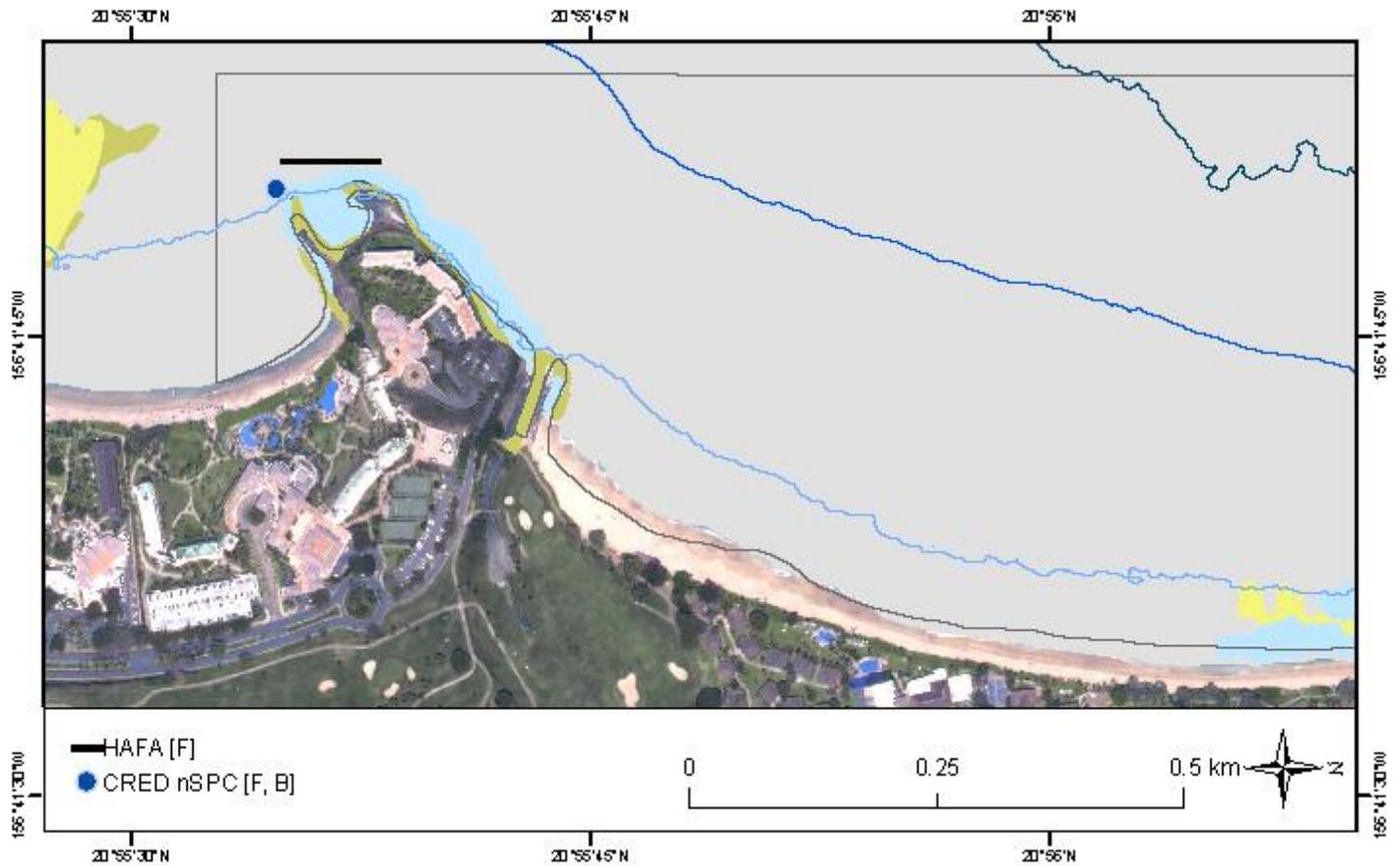


Figure 4. Black Rock Section.

Summary

This section of coastline has relatively little reef or hardbottom habitat, and is not a priority area for coral reef surveys.

Kahekili HFMA Section

Available Survey Data

There is abundant survey data from the Kahekili section, including the intensive randomized belt transect ('KHFMA') surveys, for which CREP and DAR staff have gathered fish and benthic data at sites haphazardly located across hardbottom and reef habitats since January 2008. The sampled area encompasses nearly all nearshore reef habitat from just south of Kahekili Beach Park to the northern edge of the spur-and-groove reef at Honokōwai Point (figures 1 & 5). Much of the reef is well developed and somewhat structurally complex, starting from close to the shoreline and extending to depths of between 25ft in the southern portion and ~55ft in the middle and northern portions. In addition, there are CRAMP benthic transects on nearshore reefs in front of Kahekili beach park that have been surveyed nearly annually by CRAMP and DAR since 1999. There have been some additional survey efforts, but those not spatially or temporally extensive enough for us to include them here given the strength of other data sources available.

In June-July 2014, CREP and DAR established 6 coral health stations on spur-and-groove reef habitat just north of Honokōwai Point (figure 5), with the intention of implementing long-term co-monitoring of coral health and demographics there.

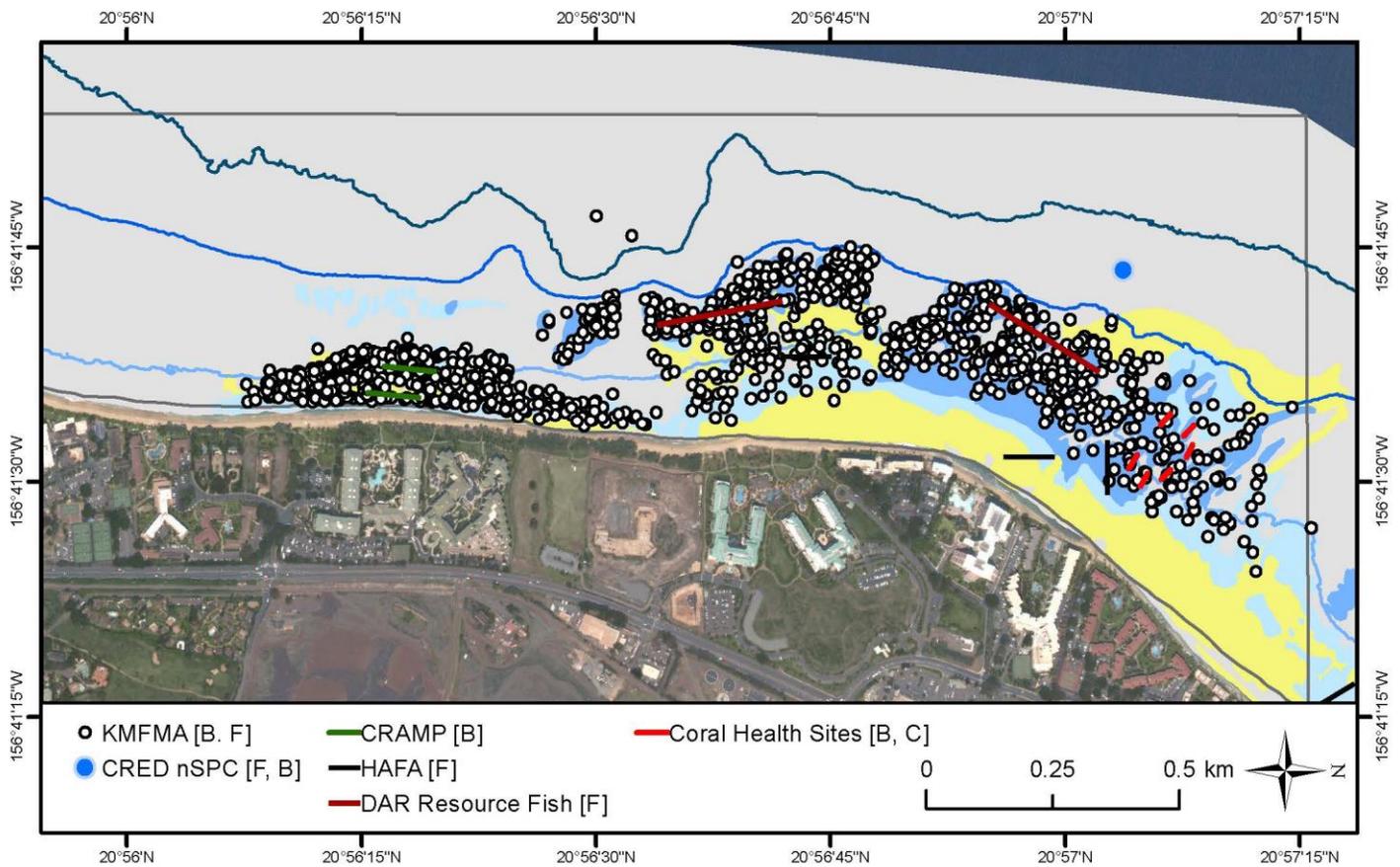


Figure 5 Kahekili Herbivore Fisheries Management Area Section.

The location of the 2 DAR resource fish sites and 4 DAR 'Hafa' stations in this section of coastline are shown in figure 5, but those data are not utilized here because the KHFMA monitoring is much more spatially. CRAMP benthic data are provided to show longer-term trends at that site.

Benthic Condition Metrics – Kahekili HFMA

Table 4a. % Cover (Mean and SE). CREP RAMP Comparisons are for sites in <60ft of water from 2010 to 2015.

% COVER (Mean and SE)	Randomized Belt Transect DAR-CREP		CREP RAMP (2010-2015)	
	5-yr Ave (2011-15)	Recent (2015)	Maui	All MHI
Hard Coral	34.2 ± 0.3	34.6 ± 0.9	18.9 ± 1.9	12.0 ± 0.5
Macroalgae	0.4 ± 0.2	0.1 ± 0.03	3.9 ± 0.6	3.6 ± 0.3
CCA	10.4 ± 1.4	14.8 ± 0.9	5.3 ± 0.5	4.1 ± 0.2

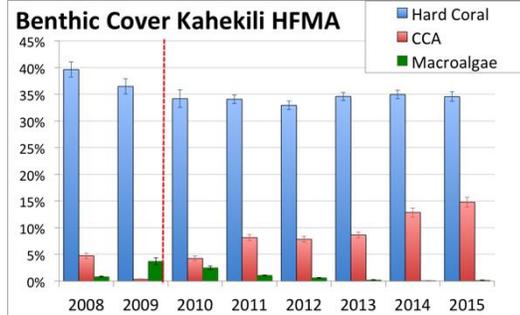


Figure 5A. Benthic Cover Trends KHFMA Monitoring

Table 4b. Demographics (Density colonies/m²) Data are Mean ± SE. CREP comparisons are for sites <60ft of water from 2013 surveys.

	Coral Health Site	CRAMP DAR-CREP	CREP RAMP	
	Recent (2014)	Recent (2010-2011)	Maui	All MHI
Juvenile colonies	4.2 ± 0.2	3.3 ± 0.5	5.1 ± 1.4	3.8 ± 0.4
Adult colonies	20.0 ± 0.9	20.5 ± 1.5	11.2 ± 2.9	6.8 ± 1.2

Table 4c. Coral Health (%). Data are Mean ± SE. CREP comparisons are for sites <60ft of water from 2013 surveys. CRAMP and CREP data collected using slightly different methods, which means that estimates are not exactly comparable (different survey areas yield somewhat different estimates of disease prevalence)

	Coral Health Site	CRAMP DAR-CREP	CREP RAMP	
	Recent (2014)	Recent (2010-2011)	Maui	All MHI
Coral bleaching	2.4 ± 0.3	0.3 ± 0.3	2.0 ± 0.5	2.0 ± 0.5
Disease				
-Growth anomalies	0.5 ± 0.1	1.1 ± 0.4	1.0 ± 0.7	0.3 ± 0.1
-Recent tissue loss	0.7 ± 0.7	0.5 ± 0.2	0.5 ± 0.2	0.1 ± 0.1

Fish Condition Metrics = Kahekili HFMA

Table 5. Biomass (g m⁻²). Data are Mean ± SE. CREP RAMP Comparisons are for sites in <60ft of water from 2010 to 2015. Note that differences in survey methods mean that biomass estimates are not exactly comparable (i.e. different methods yield somewhat different biomass estimates). Trends show annual biomass visually marked as green (pre-closure years) and red (post establishment of KHFMA).

BIOMASS (g /m ²)	Randomized Belt Transect (‘KHFMA’ type) DAR-CREP		CREP RAMP	
	5-yr Ave (2011-15)	Recent (2015)	Maui	All MHI
All Fishes	47.3 ± 2.9	49.1 ± 3.0	25.8 ± 2.3	26.3 ± 1.1
Parrotfish	7.2 ± 0.5	7.4 ± 0.6	2.8 ± 0.6	2.4 ± 0.2
Surgeonfish	18.3 ± 1.4	18.5 ± 1.4	10.0 ± 1.0	9.3 ± 0.4

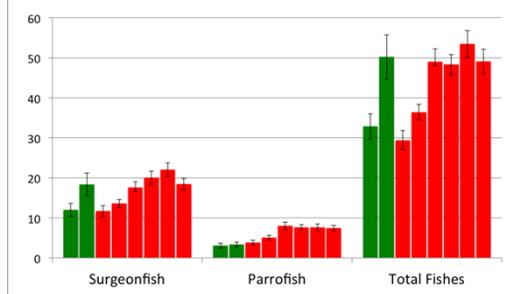


Figure 5B. Fish Assemblage Trends KHFMA Monitoring

Long-Term Benthic Data - Kahekili CRAMP

This data comes from the CRAMP stations at 3 and 7m deep towards the southern end of the reef in front of Kahekili Beach Park. Note that data from before 1999 comes from the site established by the Pacific Whale Foundation in 1994. Although efforts were made to overlay the CRAMP site on the site of the Pacific Whale Foundation site, the location and layout of the replicate transects at the sites differs between methods.

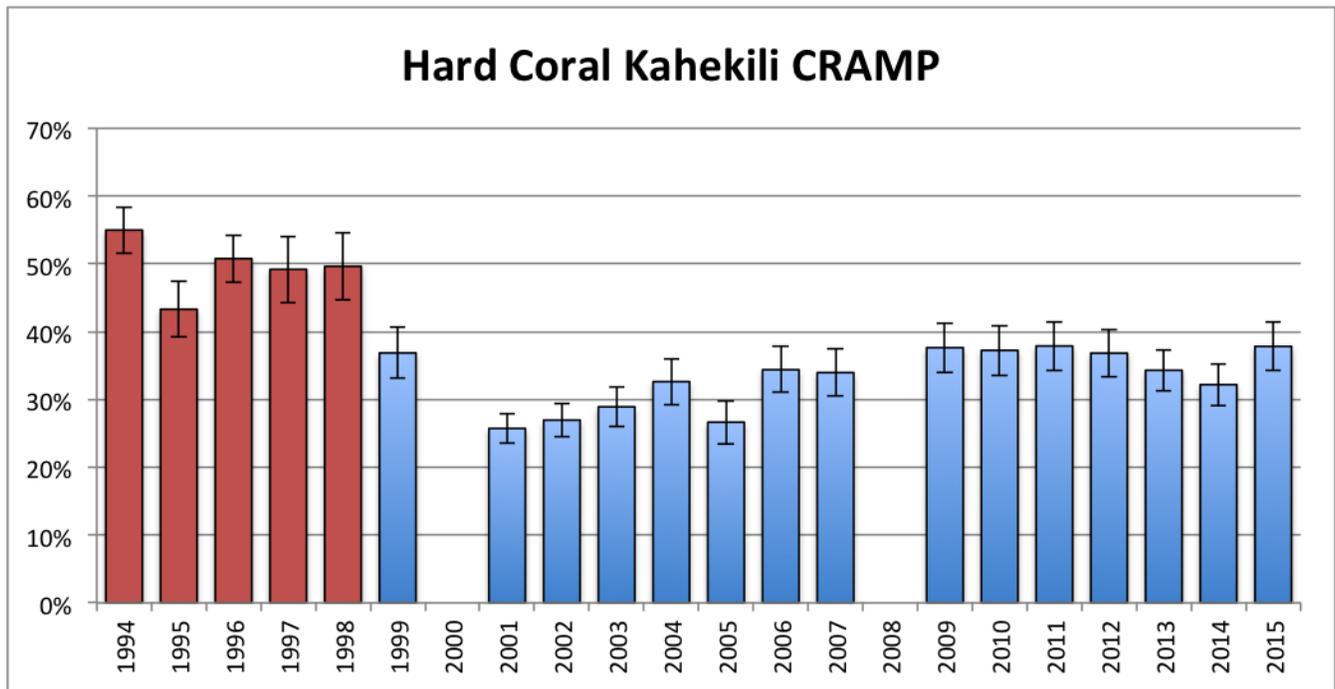


Figure 7. CRAMP coral cover from Kahekili

Summary

Nearshore hardbottom areas in this section of coastline contain large areas of coral habitat, including coral rich shallow and medium-depth habitats south of Honokōwai point, and well-developed spur-and-groove habitats around Honokōwai Point. Long-term data from the CRAMP transects in front of Kahekili beach park indicates a sharp decline in coral cover in the late 1990s; but it appears that coral cover partially recovered at those stations over the next few years, and has been relatively stable there since around 2009.

The spatially and temporally comprehensive data from the KHfMA survey program provide evidence of recent change in fish and benthos, subsequent to establishment of the Kahekili HFMA in 2009, including clear upward trends in biomass of herbivorous fishes and in cover of crustose coralline algae (CCA). Survey data provide some indication of a small upward tick in coral cover across the area as a whole from a low point in 2012. However, by the end of 2015, the scale of that increase was not statistically significant. Given timelines of recovery evident from studies of coral reef marine reserves elsewhere in the world, there is probably considerable scope for further and larger changes to reef condition in coming years if protection is maintained.

Overall, compared to the available Maui Island and MHI comparisons, coral cover and fish populations at Kahekili, including herbivorous fishes, are in relatively good states, and appear to have been improving. It is important to note, however, that we do not yet have data gathered after the late-summer 2015 coral bleaching event. It is likely that there has been some coral mortality as a result of that event, which will become evident as newer data becomes available.

North Honokōwai /Mahinahina Section

Available Survey Data

Reef and hardbottom habitats in this section are rather variable, with some patches of well-developed complex reef, but also large areas of sandy or pavement habitat with little coral. The available survey data includes the ‘Mahinahina’ CRAMP stations at 3m and 10m deep, where benthic cover have been surveyed since 2004, and the DAR ‘resource fish’ survey site, which is located over the deeper CRAMP station, and where fish assemblages have been surveyed 1 to 3 times annually in recent years. DAR and CREP established 6 coral health permanent monitoring stations in June 2014. As noted above, randomized fish and benthic belt transect surveys using the ‘KHFMA’ approach have been conducted in this section since 2015. Those are spread across the coral habitats in this section and therefore give best data on overall status. The location of the 3 ‘shallow-water’ HAFA sites in this section are shown in figure 8 below, but because of rather limited effort and because data are only representative of very shallow inshore habitats, they are not used for assessment of status or trends

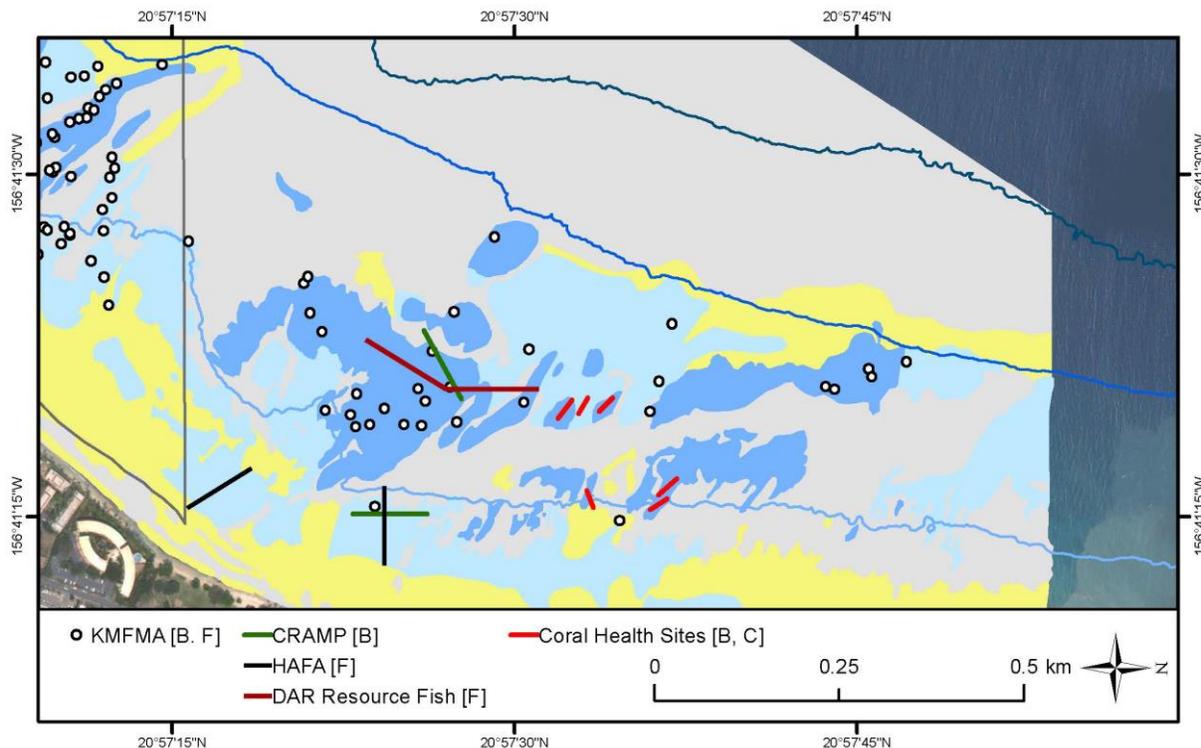


Figure 8. North Honokōwai/Mahinahina Section. Note that the vertical boundary to the left of the figure is the northern edge of the Kahekili HFMA. Only survey sites north of that boundary are in this section of coastline. ‘KHFMA’ surveys in this and comparable figures are surveys using the randomized belt transect approach developed for monitoring the Kahekili HFMA.

Benthic Condition Metrics – North Honokowai/Mahinahina

Table 6a. Mean ± SE benthic cover from coral health site surveys and from randomized belt transects. Randomized belt transects method were conducted in the Coral 10-50% and 50-90% habitat (dark and light blue in Fig. 8), with sector averages derive from those two habitats equally weighted. CREP RAMP comparison come from the analysis of 2010-2015 RAMP benthic images from all sites at comparable depth (<60ft).

	Randomized Belt Transects Coral 10-50% & 50-90%	Coral Health Sites	CREP RAMP (2010-2015)	
	2015	2014	Maui	All MHI
Hard Coral	33.4 ± 3.7	23.7 ± 8.8	18.9 ± 1.9	12.0 ± 0.5
Macroalgae	0.0 ± 0.0	1.2 ± 0.7	3.9 ± 0.6	3.6 ± 0.3

CCA	7.8 ± 1.6	0.0 ± 0.0	5.3 ± 0.5	4.1 ± 0.2
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Table 6b, Demographics (Density colonies/m²) Data are Mean ± SE. CREP comparisons are for sites <60ft of water from 2013 surveys.

	'Coral Health' sites	CREP RAMP	
	2014	Maui	All MHI
Juvenile colonies	9.2 ± 2.5	5.1 ± 1.4	3.85 ± 0.4
Adult colonies	9.9 ± 7.4	11.2 ± 2.9	6.8 ± 1.2

Table 6c. Coral Health (%). Data are Mean ± SE. CREP comparisons are for sites <60ft of water from 2013. CRAMP and CREP data collected using slightly different methods, which means that estimates are not exactly comparable (different survey areas yield somewhat different estimates of disease prevalence). *Coral condition surveys conducted in Oct 2014;

	"Coral Health" sites	CREP RAMP	
	2014	Maui	All MHI
Coral bleaching	0.2 ± 0.2	2.0 ± 0.5	2.0 ± 0.5
Disease -Growth anomalies -Recent tissue loss	0.0 0.0	1.0 ± 0.7 0.5 ± 0.2	0.3 ± 0.1 0.1 ± 0.1

Fish Condition Metrics – North Honokowai/Mahinahina

Table 7. Mean ± SE fish biomass from Mahinahina DAR Resource Fish site and randomized belt transect surveys. Note that Maui resource fish average comes from all other resource fish sites at comparable depth in Maui. Belt transect surveys were conducted in 2015 in Coral 10-50% and Coral 50-90% habitat (light and dark blue habitats in figure 8). Those data are here compared against averages of CREP surveys around Maui in 2010-2105.

BIOMASS (g /m ²)	Randomized Belt Transect 2015 Mahinahina	CREP RAMP 2010-2015 Maui	DAR Resource Fish (2011-2015)	
			Mahinahina	Maui
All Fishes	66.2± 21.7	25.8 ± 2.3	4.2 ± 1.3	16.1 ± 1.3
Parrotfish	2.7 ± 2.0	2.8 ± 0.6	1.1 ± 0.5	2.6 ± 0.2
Surgeonfish	30.9 ± 14.9	10.0 ± 1.0	2.3 ± 0.8	7.7 ± 0.8

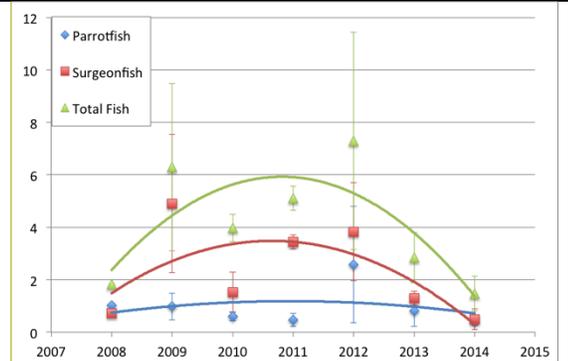


Figure 8A. Fish Assemblage Trends from Mahinahina Resource Fish Surveys.

Long-Term Benthic Data - Mahinahina CRAMP

This data comes from the CRAMP stations at 3 and 10m deep. Note that this is the average of the 3m and 10m stations. Over the 2004-2015 period, coral cover has been relatively stable, but overall mean cover in 2015 was around 90% of its value in 2004 ($31.0 \pm 3.2\%$ in 2004; $26.8 \pm 2.3\%$ in 2015; that decline was marginally significant at the deeper station ($p < 0.05$). However, there is some indication of a small increase between 2014 and 2015. Note that latest data presented here are from summer of 2015, i.e. before any potential mortality caused by the 2015 Maui and MHI bleaching event.

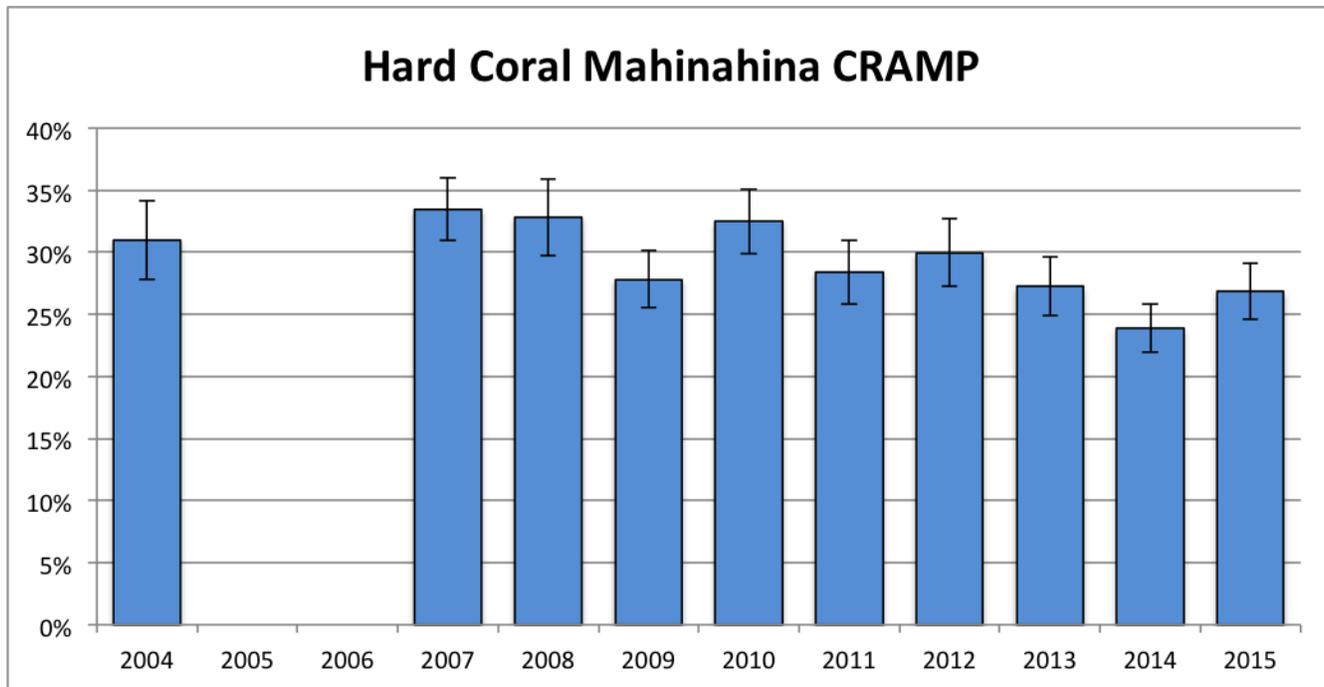


Figure 9. CRAMP coral cover from Honokōwai

Summary

Reef and hardbottom habitats in this section of coastline are highly variable, but with some patches of high-cover coral-rich habitat. The high level of patchiness of the reefs in this area make it difficult to know how representative are any trends drawn from surveys of limited areas, such as the CRAMP and 'Resource Fish' surveys.

However, that information is nevertheless highly useful for the specific location of the surveys and is the only trend data we have for this section. At the Mahinahina CRAMP sites, there has been a small decline in coral cover over the last decade – with cover in 2015 being around 1/10th below what it was when survey began in 2004. However, cover still averages a little below 30%. Biomass of target fishes, including herbivorous fishes, has been consistently low in the 'resource fish' surveys conducted between 2008 and 2014. Because of low sample size it's not possible to draw firm conclusions about trends, however biomass values have been particularly low in recent years.

Randomized belt transect surveys (i.e. the 'KHFMA' method) were relatively widely spread across the coral reef habitat in this section. Here we use data only from coral rich areas (light and dark blue areas in figure 8). Those indicate that mean coral cover was a little over 30%, and that fish, including herbivore, populations were in reasonable condition. Surgeonfish biomass was boosted by an encounter with a large school of planktivorous surgeons, and therefore derived mean biomass is probably unrealistically high. Overall, populations of those groups appear about average or slightly below similar coral habitats around Maui. Parrotfish biomass and CCA cover were substantially lower than inside the Kahekili HFMA.